MULTI-COMPANY INTERACTIONS

We value our collaborations with industry, other government agencies, and academic institutions. Multi-company interactions provide a forum by which we bring together different sectors of industry toward common objectives. Many benefits are realized. First, these collaborations create consensus and synergism in critical areas of research, and they make possible the achievement of more ambitious goals. Secondly, we decrease the time and cost of development, and more quickly overcome technology barriers. Collaborations also enhances the exchange of information, plus focuses and keeps entire fields more up-to-date. Lastly, collaborations encourages faster industrial adoption of technology, thereby increasing U.S. productivity at an accelerated rate. Examples of recent multi-company collaborations follow.

Solder Interconnect Design

Purpose:
The main objective of this program is to develop modeling tools for predicting the geometry of small-scale solder joints with a wide range of starting configurations of interest to industry. Implicit in the development of such tools is the necessity of developing the computational methods for importing solder geometries to other models of processing and reliability. With these objectives in mind the Solder Interconnect Design Team (SIDT) seeks to establish and foster an industry-academia-national laboratory working group on solder joint design for the exchange of information and collaboration on topics of special importance. The SIDT acts as forum for discussion of the calculations and models and, through the center for Theoretical and Computational Materials Science, provides access to software through the Internet/WWW In addition, the SIDT also seeks to hold workshops and symposia promote collaboration and bring the community toward a consensus on the features required for a useful solder modeling system.

NIST Investigators:
J. A. Warren (Metallurgy), C. A. Handwerker (Metallurgy) Frank Gayle, Daniel Josell, Adam C. Powell IV (Now at MIT), Bill Boettinger and Kil-Won Moon

External Participants:
The SIDT is an industry-academia-government laboratory collaboration. External Organizations represented at different workshops include Edison Welding Institute, DEC, Motorola, BOC Gasses, Ford Motor Co., Lucent Technology, AMP. Rockwell, Delco, Texas Instruments (Raytheon), Susquehanna University, University of Colorado, University of Massachusetts, University of Wisconsin, University of Loughborough, Lehigh University, University of Greenwich, Marquette University, RPI, University of Minnesota, and Sandia National Laboratory in addition to NIST. An ATP/CRADA with Boeing and the ATP program in optoelectronics concluded this year.

MSEL's Role:
The NIST Solder Interconnect Design Team, with support from NIST's Center for Theoretical and Computational Materials Science, has been formed to address several pressing issues in the design and fabrication of circuit boards. This multi-billion dollar industry is highly dependent on solder

interconnects as the dominant method for attaching chips to a circuit board. Over the past five years, in partnership with both academic and industrial researchers, the Team has established an agenda for solving modeling problems concerning equilibrium solder joint shapes, and the consequential thermal and mechanical properties of the formed joint. Our ultimate goal is to provide the industrial community with a suite of useful software tools for solder interconnect design, and to provide solved test problems (available electronically on the World Wide Web). With this in mind we are actively supporting the development of software that will interface the public domain program Surface Evolver, which has been shown to be extremely effective for computing equilibrium solder meniscus shapes. Problems that are under current consideration include tombstoning (lifting of a small component off the circuit board), forces on the gull wing lead, solidification of the solder interconnect, reactive wetting (dissolution and the formation of intermetallics), optoelectronic interconnects, and the behavior of underfill.

Outcome:
Development of improved software tools for the modeling of solder interconnects. As a direct result of SIDT activities, most academic engineers who work in the area of solder interconnect issues in electronic packaging have now heard of the Surface Evolver. Indeed, we field inquiries from researchers on a frequent basis and refer them to our WWW page (approximately 1500 software downloads per year). The infiltration of this solder modeling tool into the relevant communities is nearly complete. The SIDT is therefore moving on to more fundamental research into the more complex, multi-physics, dynamic processes that occur during solder reflow. More material can be found at http//www.ctcms.nist.gov/programs/solder.

Micromagnetic Modeling Activity

Purpose:
The micromagnetic modeling activity group (muMAG) was formed in 1995 with two technical goals 1) the development and circulation of standard problems, and 2) the development of publicly available micromagnetic software. A third function was to provide a focal point and communications channels for discussions between scientists and engineers working in micromagnetics.

NIST Investigator:
Robert D. McMichael (Metallurgy); muMAG is primarily an MSEL-ITL collaboration, with MSEL contributing more heavily to the standard problems and ITL driving the public code work. EEEL is also involved in using the public code to model experimental measurements of switching dynamics in MRAM.

External Participants:
The main industry that has been concerned with micromagnetics is the magnetic recording industry, but the leading edge is currently in non-volatile magnetic random access memory (MRAM). Future uses of micromagnetics may be found in "spintronics" related fields currently being supported through DARPA. We count membership in muMAG by the electronic mailing list which has 168 addresses distributed among 20 universities, 11 companies, 6 government labs and 23 foreign countries. The dominant companies are IBM, with 8 members and Seagate with 7 members.

Participation in muMAG ranges from passive interest in our progress to active solution of standard problems and contributions for the public software.

MSEL's Role:
MSEL focuses its efforts primarily toward standard problems and furthering the field of micromagnetic modeling. Micromagnetic modeling is concerned with predicting the domain structure and dynamics of the magnetization vector in a material.

Outcome:
The muMAG projects have successful outcomes. We now have two (out of three) standard problems that have been independently solved and favorably compared. These results can be used as benchmarks for newly developed micromagnetic software. We are now distributing public software (reference code) for micromagnetic computations in two dimensions. Future expected outcomes include standard problems for calculations of magnetic dynamics and three-dimensional public code.

Deformation Working Group - Advanced Computational Models and Experiments for Deformation of Aluminum Alloys

Purpose:
The purpose of this collaboration is to develop a materials-based model of the plastic deformation of aluminum alloys which can be used to predict the changes in mechanical properties during metal forming operations. The model would be incorporated into existing commercial finite element programs. The model could also be used to facilitate the design of improved alloys for industrial use.

NIST Investigators:
Lyle Levine (Metallurgy), Robb Thomson (NIST Fellow, Emeritus; Metallurgy Guest Researcher), Yunsic Shim (Metallurgy Guest Researcher), James Fink (Metallurgy), Gabrielle Long (Ceramics), and David Black (Ceramics).

External Participants:
It is a joint project between NIST, the Aluminum Company of America (ALCOA), MARC Analysis Research Corporation, Pacific Northwest National Laboratory, and Washington State University. Each of the participants is supporting its own part of the program using internal funds, including the support of 10 non-NIST Ph.D. researchers.

MSEL's Role:
MSEL's role includes developing the fundamental statistical physics model of the deformation process and conducting critical experiments using MSEL's unique X-ray synchrotron facilities at both the Advanced Photon Source and the National Synchrotron Light Source. Use of the NIST Center for Neutron Research is also anticipated.

Outcome:
There are many important applications of this technology and following is one example. If

successful, this program would greatly decrease the costs of designing stamping dies for aluminum alloys. The high cost of designing these dies is the primary reason why automobile bodies are not made using aluminum alloys. Aluminum is preferable for this role since it would allow the production of much lighter automobiles, thus improving fuel efficiency.

Deformation Working Group - Center for the Accelerated Maturation of Materials (CAMM)

Purpose:
The purpose of the CAMM is to develop an integrated set of computational tools aimed at mimicking, and subsequently supplementing and eventually replacing, many of the experimental efforts which are required for materials development.

External Participants:
Nine universities, five government laboratories, and 20 companies. The companies are Alcan International, Allegheny Ludlum, Allied Signal Engines, Boeing, Brush Wellman, Inc., Century Aluminum, Ford, GE Aircraft Engines, Honda, Howmet, Ladish Co., Inc., Lockheed Martin, MTS / NanoInstruments, Philips Electronic Instruments, Reference Metals, Rolls Royce-Allison, Timet, UES Inc., UTRC / Pratt & Whitney, and Wyman-Gordan Company. All participating companies have agreed to pay $30,000 per year to the CAMM to participate. This collaboration is not yet fully funded. The desired funding is $43.25 M / 5 yr. and funding commitments so far total $23.5 M / 5 yr. The CAMM is intended to be a ten year program.

MSEL's Role:
MSEL's role includes developing the fundamental statistical physics model of the deformation process and conducting critical experiments using MSEL's unique X-ray synchrotron facilities at both the Advanced Photon Source and the National Synchrotron Light Source. Use of the NIST Center for Neutron Research is also anticipated. The primary difference between this and the Advanced Computational Models and Experiments for Deformation of Aluminum Alloys collaboration is that the CAMM has a broader materials emphasis (aluminum alloys, Ti alloys, and Ni-based super alloys). The program is also aimed more at alloy design whereas the first collaboration primarily emphasizes metal forming operations.

Outcome:
The anticipated outcome is a large decrease in the time and cost of developing new alloys for aerospace, automotive, and other applications.

Robotic Weld Cell Interfaces

Purpose:
Develop a standard interface, so presently incompatible weld cell components can communicate with each other.

NIST Investigators:
T.A. Siewert (Materials Reliability), T.P. Quinn (Materials Reliability), W. Rippey (Manufacturing

Engineering Laboratory) and Bob Russell (Manufacturing Engineering Laboratory)

External Participants:
Two members from Lincoln Electric Co. (major producer of equipment), two members from Miller Electric Co. (major producer of equipment), various other members from sensor developers and general interest companies.

MSEL's Role:
Tim Quinn, Chairman of AWS Committee A9 on computerization of Welding Data, T. Siewert and W. Rippey are members. Also, T. Siewert is Chairman of Subcommittee A9C on Data Logging. NIST developed a draft of a weld cell activity model, and offered it to the committee. NIST has constructed a welding testbed (in Manufacturing Engineering Laboratory) that is being used to evaluate the specifications. The testbed is based on a state-of-the-art, high-speed computing and communications (network) infrastructure. The testbed includes a welding robot and several arc sensing systems.

Outcome:
American Welding Society Standards, including a description of the welding communication protocols.

Library of Green's Functions on the Internet

Purpose:
To set up a library of Green's functions on the Internet for stress analysis and nondestructive characterization of materials of industrial interest.

NIST Investigator:
Vinod Tewary (Materials Reliability)

External Participants:
Frank Rizzo (Iowa State Univ.), Ambar Mitra (Iowa State Univ.), John Berger (Colorado School of Mines), Laura Bartollo (Kent State Univ.), Adam Powell (MIT), Laocet Ayari (Ball Aerospace), Lingyun Pan (Automated Analysis Corporation). In addition, other industries such as Allied Signal and Caterpillar Inc. are exploring the utility of the Green's functions library.

MSEL's Role:
New computationally efficient techniques for calculating Green's functions are developed at MSEL. These techniques are used in the boundary element formulation for materials of industrial interest. Two workshops, sponsored by CTCMS, were organized in which researchers from NIST, academia, and industry participated. A GF consortium and working group has been formed at the CTCMS with NIST in the coordinating role.

Outcome:
An interactive web site http://nistgf.kent.edu has been created where Green's functions and the

software are available. More powerful software for anisotropic solids will be available by the end of Feb 2000. The web site provides a virtual meeting place for the GF Consortium and has provision for exchange of papers and reports, software, literature references, and problem bank. The web site is expected to be used by the industry as well as teachers and students at the universities.

Orthopedic Wear Consortium

Purpose:
The purpose of the consortium is to develop accelerated wear test methodology to screen biomaterials used in joint replacements.
NIST Investigators:
Stephen Hsu (Ceramics) and John Tesk (Polymers)

Participants:
Polymers Division and Ceramics Division cooperate with four industrial companies Biomet, Johnson and Johnson, Stryker Howmedica, and Zimmers. The technical expertise and facilities in the two divisions were crucial to coalesce the industrial experiences to solve the problem.

MSEL's Role
An accelerated wear test method has been developed that can screen materials of known performance in a test that lasts seven days instead of eight months.

Outcome
Work is continuing to validate the short term testing in terms of long term performance.

National Storage Industry Consortium

Purpose:
The established purpose of the NSIC is to develop the next generation of data storage technologies and NIST is supporting the measurements requirements of the NSIC effort. The Consortium has established a technology roadmap and organized five working technical groups to develop the next generation of technologies.

NIST Investigator:
Stephen Hsu (Ceramics)

External Participants:
Corporate Members: Advanced Research Corp., Polaroid, Aprilis, Inc., Quantum ,Calimetrics, Read-Rite, Cirrus Logic, Rockwell Science Center, Eastman Kodak, Saint-Gobain Industrial Ceramics, ECD (Energy Conversion Devices), Seagate Technologies, EMC Corporation, Silicon Graphics, Headway Technologies, Siros Technologies, Inc., Hewlett-Packard, Storage Technology, Hutchinson Technology, Sun Microsystems, IBM, Texas Instruments, Imation, Veeco Instruments, Komag, VTC, Lucent Technologies, Western Digital, Maxtor, 3M.

Associate Members: Argonne National Laboratory, Stanford University, Arizona State University, University of Akron, Bucknell University, University of Alabama, Carnegie Mellon University, University of Alberta, Georgia Institute of Technology, University of Arizona, Harvard University, University of California Berkeley, IDEMA, University of California San Diego, Lawrence Berkeley National Laboratory. University of Central Lancashire, Lawrence Livermore National Laboratory, University of Colorado Boulder, Los Alamos National Laboratory, University of Dayton, Massachusetts Institute of Technology, University of Idaho, Montana State University, University of Minnesota, NIST, University of Nebraska, Northwestern University, Vanderbilt University, Ohio State University, Washington University, Santa Clara University

MSEL's Role:
MSEL's participation in two of the five working groups has 1.) enabled a direct linkage of the NIST's effort to industrial concerns and industrial research results ; 2.) Focused NIST research to conduct basic research in measurements and standards research critical to an ongoing industrial effort; 3.) Provided unique facilities to assist in the effort such as the Ultra-soft X-ray Near Edge Fine structure spectroscopy for monolayer film characterization.

Outcome:
We anticipate NIST will contribute significantly to NSIC's effort in rapidly developing next generation of data storage technology and maintain U.S. competitiveness.

NIST/University/Industry Consortium for Neutron Spectroscopy

Purpose:
To greatly advance U.S. capabilities in neutron spectroscopy for studies of new materials.

NIST Investigators:
Jack Rush (NCNR), Dan Neumann (NCNR), Terrence Udovic (NCNR)

External Participants:
The NIST Reactor Radiation Division has joined with the University of Pennsylvania and the University of California at Santa Barbara, and their industrial partners DuPont, Hughes Aircraft, and Allied Signal.

MSEL's Role:
Joint efforts will be focused on the development and operation of a new high intensity neutron spectrometer with unparalleled sensitivity to be installed at the NIST reactor. The total outside investment for this facility will be $1.5 M over three years ($750k NSF, $600k Penn & UCSB, and $150k Industry). In addition to leading the development of this instrument, NIST scientists will pursue joint generic and strategic research on new materials (e.g. catalysts, lightweight batteries, conducting polymers, fullerenes) with the university/industry research teams, who will have postdocs and students stationed at the NIST reactor. One quarter of the time on the new facility will be allocated to the general scientific community on the basis of scientific merit through the NIST proposal system.

Outcome:
This next generation spectrometer is expected to increase U.S. measurement capabilities in neutron vibrational spectroscopy by a factor of 100 thereby enabling researchers to study samples as small 10 mg.

Surface and Interface Collaboration

Purpose:
To develop of two new instruments at the NIST Center for Neutron Research (NCNR)

NIST Investigators:
Chuck Majkrzak (NCNR), Sushil Satija (NCNR)

External Participants:
The Center for Interfacial Engineering of the University of Minnesota (with over 40 associated industrial firms throughout the U.S.)

MSEL's Role:
The NCNR provides research capabilities that are unmatched in the United States and are comparable to any in the world for materials science and chemistry research.

Outcome:
A 1984 National Academy of Sciences panel recommended the development of this internationally competitive cold neutron research facility as the most urgent need among large-facility improvements for U.S. science and technology. The instruments developed provide researchers unique probes for studying microscopic characteristics of materials critical for improving the processing of complex chemicals, coatings for photographic, optical, and magnetic films, and microelectronic fabrication.

Residual Stress Technique Comparison

Purpose:
A round robin in the area of residual stress determination The goal of the collaboration is to clarify the applicable range of each technique, strengths and limitations.

NIST Investigators:
Hank Prask (NCNR) and Paul Brand (NCNR)

External Participants:
John Deere, Technology for Energy Corp. (TEC), and Oak Ridge National Laboratory

MSEL's Role:

The NCNR provides research capabilities that are unmatched in the United States and are comparable to any in the world for materials science and chemistry research.

Outcome:
Neutron and x-ray diffraction, and holographic/hole drilling are being used to study the residual stress distribution in induction hardened steel rods.

MALDI-MS Interlaboratory Comparison

Purpose:
Develop measurement protocols for quantification of MALDI-MS measurements of molecular mass distributions of synthetic polymers. To assess the current status, an interlaboratory comparison was conducted on a NIST-supplied polystyrene that NIST characterized by traditional methods of light scattering, NMR and IR.

External Participants:
NIST Investigators: Charles Guttman (Polymers), William Wallace (Polymers), William Blair (Polymers), Robert Goldschmidt (Polymers), Bruno Fanconi (Polymers) and David VanderHart (Polymers)

External Participants:
Eastman Chemicals, Lab Connections, Air Products and Chemicals, ICI Technology, Bruker Daltonics, Zeneca Specialties, Union Carbide, Charles Evans & Associates, DuPont, BF Goodrich

MSEL's Role:
Organized the interlaboratory comparison through the Polymer Interest Group of the American Society of Mass Spectrometry, had a special polystyrene synthesized so that number average molecular mass could be determined by NMR, conducted characterization of mass average molecular mass by light scattering, distributed the polystyrene to participating laboratories, collected and analyzed test results and reported findings to mass spectrometry community.

Outcome:
In the near term NIST will issue this polystyrene as an SRM certified for molecular mass by conventional methods and include the MALDI-MS of the material as a measure of mass distribution. We envision that laboratories engaged in MALDI-MS of synthetic polymers will purchase this SRM to assess the quality of their measurements. In the longer term, measurement protocols will be developed to quantify MALDI-MS measurements on synthetic polymers.

Permittivity of Polymer Thin Films in the Microwave Range

Purpose:
Develop test procedures for dielectric characterization of thin films at microwave frequencies, up to 20 GHz. Evaluate permittivity, dispersion and relaxation of high-k and low-k dielectric films. Evaluate dielectric characteristic of high-k polymer composites provided by NCMS for the Integrated

Capacitance Project.

NIST Participants:
Jan Obrzut (Polymers), C.K.Chiang (Polymers), R. Nozaki (Polymers), R. Popielarz (Polymers)

External Participants:
Allied Signal, DuPont, 3M, Polyclad, Terephane- materials suppliers. Hadco, IBM, Litton, Merix, Raytheon, Delphi-Delco, ViaSystems test samples fabrication. TI, IBM, Penn State Univ. thermo-mechanical measurements. NCMS,- platform for interaction between members of the project.

MSEL's Role:
A microstrip test specimen and test protocol has been developed for dielectric measurements of polymer composite films. The technique is appropriate for films as thin as 10 μm having dielectric constant of 50 at frequencies of up to 5 GHz. This new capacity is essential for wireless communication and high-speed electronics where new polymer composites are being used to make embedded passive components. Using the new microstrip test specimen the microwave permittivity of several commercially developed high dielectric constant research formulations was accurately determined for the first time. It has been determined that one of the key factors controlling the dielectric properties of the composite is the dielectric constant of the polymer matrix. To satisfy requirements of future electronic technologies new polymers are needed that exhibit at microwave frequencies dielectric constant value in the range of 15-20.

Outcome:
It is expected that the effort of this research program will result in a new standard test method for high frequency permittivity measurements of thin dielectric films. The industry needs such a method to test materials and devices used by the wireless communication technologies. This work is also aimed at exploiting a fundamental mechanism which controls the dielectric properties of polymer composites. The outcome will help improve fundamental understanding of the limitations and capabilities of polymer composites and will facilitate formulation of materials with desirable dielectric characteristics.